THE ASTROPHYSICAL JOURNAL, Vol. 150, December 1967

I-1

EVIDENCE FOR X-RADIATION FROM THE RADIO GALAXY M87*

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Received November 17, 1967

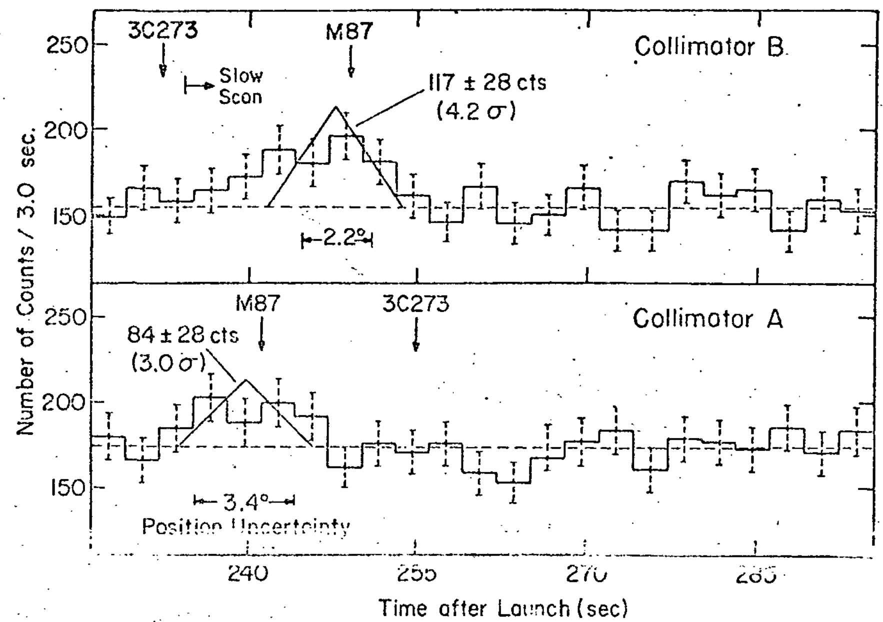

FIG. 3.—Counting rates versus time for the two collimators. The triangular functions are the idealized responses for the point sources with the most probable transit times and intensities (see text). The angular equivalent of the transit-time uncertainty is indicated below each peak.

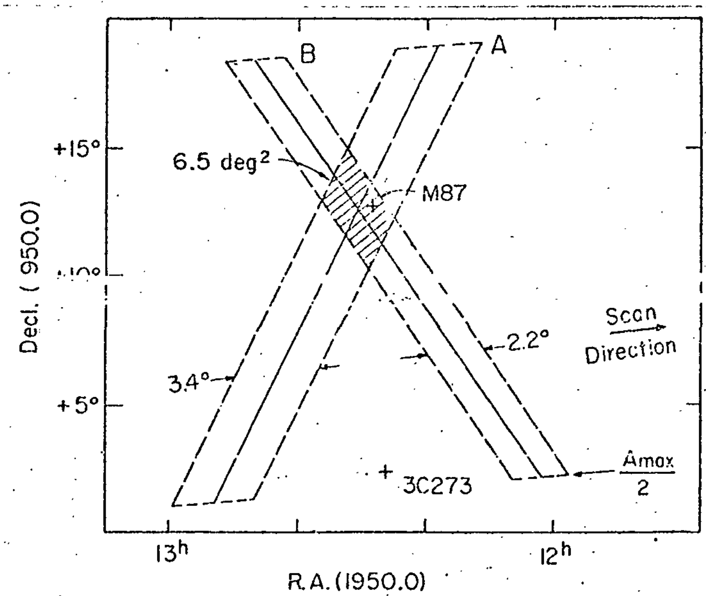

FIG. 4.—The celestial regions defined by the peaks in the data of the two banks of counters, A and B. The regions shown are those which were viewed with a counter area of more than ½ the total area (A_{max}); that is, they represent the central 20° of the 40° field of view. The celestial area defined in common by the two regions (*hatched area*) includes M87.

THE ASTROPHYSICAL JOURNAL, Vol. 152, June 1968

I-2

CELESTIAL POSITIONS OF X-RAY SOURCES IN SAGITTARIUS*

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Received January 24, 1968

ABSTRACT

During a sounding rocket flight on July 7, 1967, the celestial positions of six X-ray sources in the Sagittarius region were measured with a typical precision of 20′. One of these sources, at $b^{II} = +9°$, is reported here perhaps for the first time. An upper limit of 6×10^{-10} erg cm^{-2} sec^{-1} was obtained for X-radiation (1.5–6 keV) from the Kepler supernova remnant SN 1604.

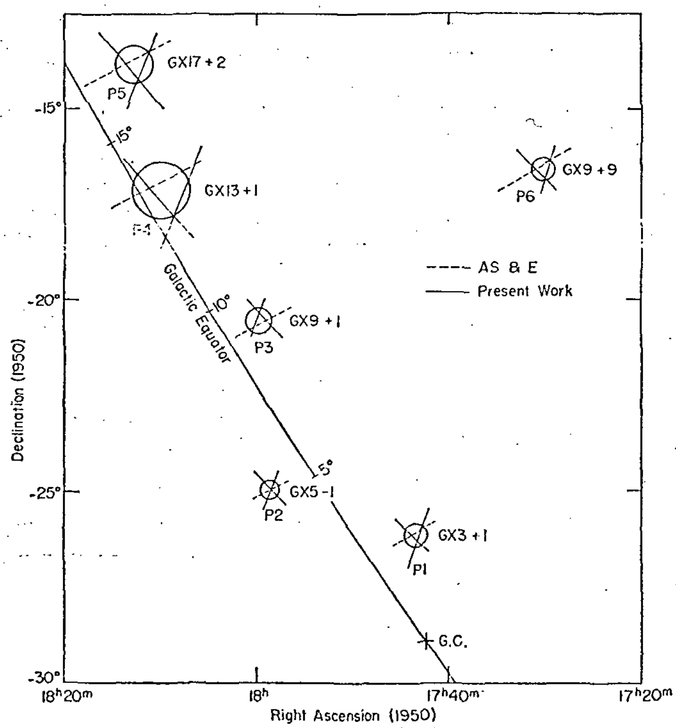

FIG. 5.—The expanded celestial plot showing the quality of the three-way intersections, the error circles, and the relation of the X-ray source positions to the galactic equator. Each error circle incloses a region wherein the sources should lie with a confidence of approximately 90 per cent (2 standard deviations). The smallest error circle is 0°.5 in diameter.

THE ASTROPHYSICAL JOURNAL, Vol. 152, June 1968

I-3

AN OPTICAL SEARCH FOR X-RAY SOURCES IN SAGITTARIUS*

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Received January 24, 1968; revised February 23, 1968

ABSTRACT

An attempt has been made to find optical counterparts for some X-ray sources in Sagittarius. An ultraviolet object ($V = 13.4$, $B - V = +1.0$, $U - B = -0.9$) was found at $\alpha(1950) = 17^h42^m.7$, $\delta(1950) = -26°10'$, 10′ from the most probable position of GX3+1.

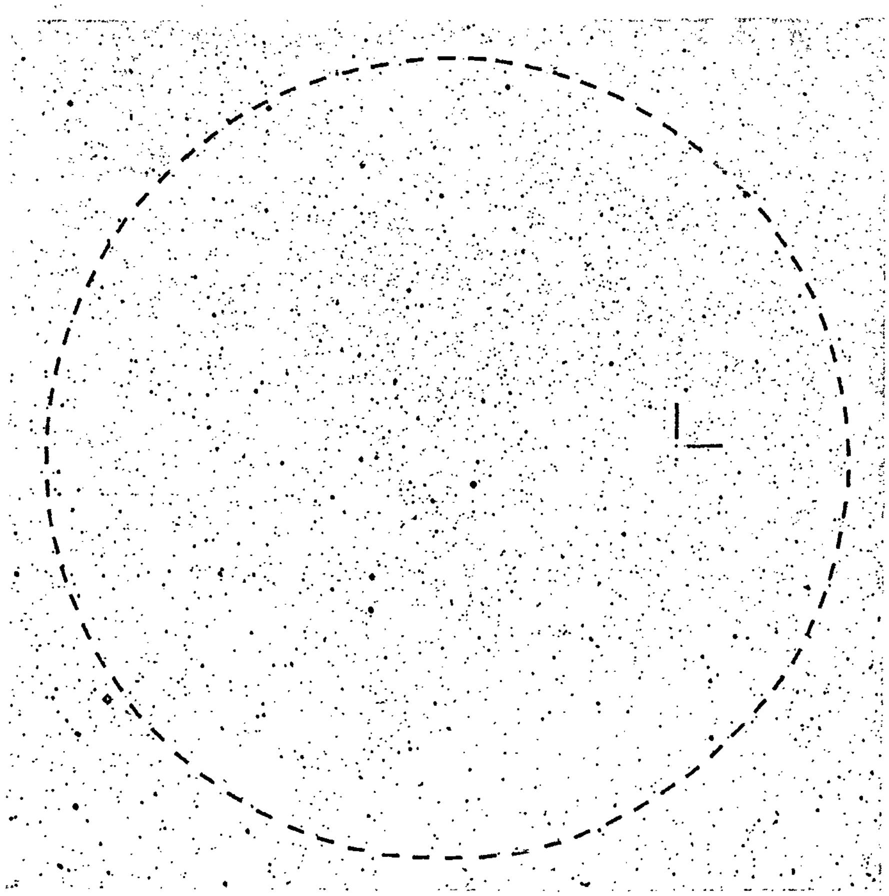

FIG. 1.—Blue photograph of the region containing source GX3+1. The error circle is 17′ in radius. The ultraviolet object discussed in the text is identified. North is up and east is to the left. Copyright *National Geographic Society–Palomar Sky Survey.*

I-4

(*Reprinted from Nature, Vol. 218, No. 5144, pp. 856–857, June 1, 1968*)

Upper Limit on X-rays from a New Supernova

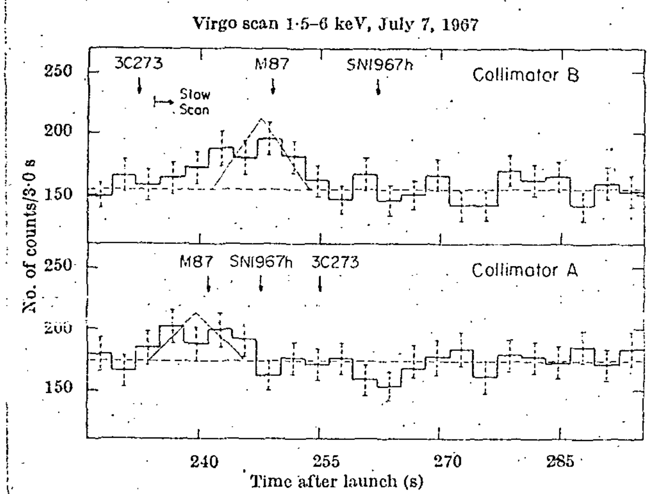

Fig. 1. Counting-rate versus time for the two collimators. The expected response for a point source is triangular in shape with a 12 s base width, as shown fitted to the data peaks attributed to *M*-87 (ref. 1).

I - 5

Low-energy X-ray Spectra of Sco X–1 and Four Sagittarius Sources

by
S. RAPPAPORT
H. V. BRADT
S. NARANAN*
G. SPADA†

Studies of long-wavelength spectra of X-ray sources provide information about their distances and about the interstellar medium.

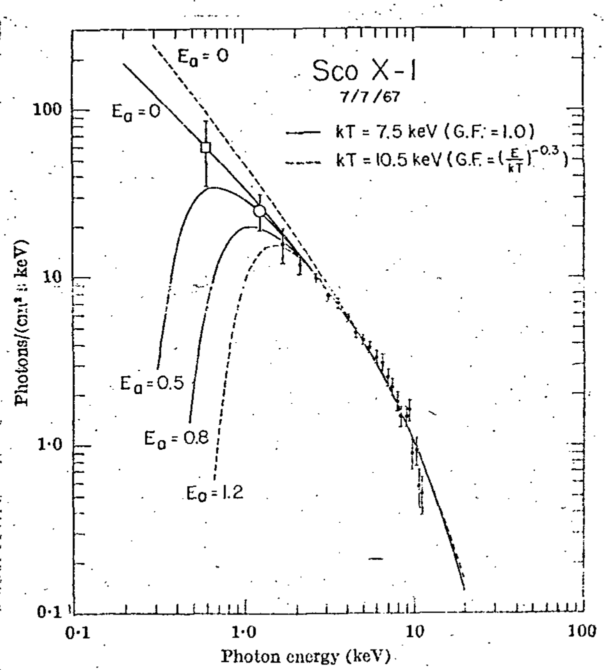

Fig. 3. The X-ray spectrum of Sco X-1 on July 7, 1967. The solid circle data points are from the beryllium window counters. The open circle and open square are from the aluminium window and 'Teflon' window counters, respectively. The solid curves represent bremsstrahlung spectra with a constant Gaunt factor (G.F.). A best fit to the data was obtained at $kT = 7{\cdot}5$ keV and at a cut-off energy, $E_a \leq 0{\cdot}5$ keV. The dashed curve with $E_a = 1{\cdot}2$ keV is the best fit bremsstrahlung spectrum with an energy dependent Gaunt factor. The corresponding no-cut-off spectrum is shown as a reference.

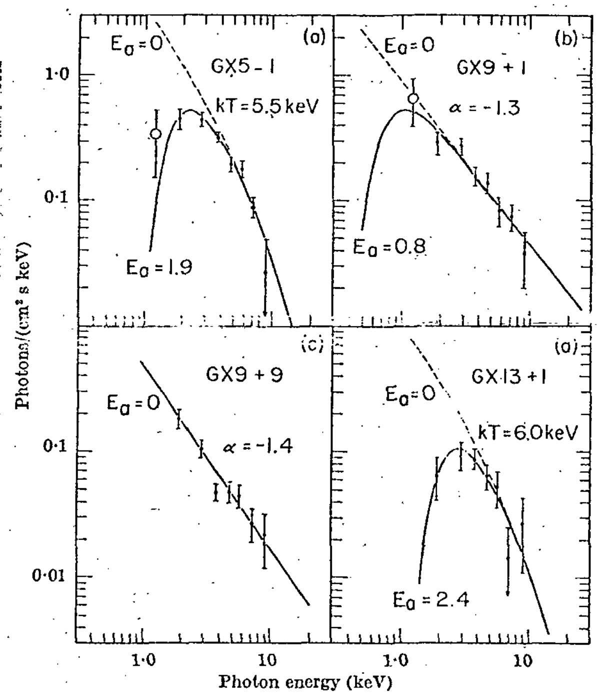

Fig. 4. The spectra of four X-ray sources in Sagittarius. The solid circle and open circle data points are from the beryllium window and aluminium window counters, respectively. The best fit bremsstrahlung spectra are compared with the data of GX5–1 and GX13+1, and the best fit power-law spectra are compared with the data of GX9+1 and GX9+9 (solid curves). The form of the bremsstrahlung spectrum is given by equation (2) with a Gaunt factor of $(E/kT)^{-0.3}$. Each dashed curve, shown as a reference, represents the same spectrum given by the associated solid curve but with no cut-off. The values of α given in (b) and (c) are the logarithmic slopes of the X-ray number spectra. The cut-off energies, E_a, are in keV.

THE ASTROPHYSICAL JOURNAL, Vol. 159, February 1970

II-1

UPPER LIMITS ON THE ANGULAR SIZES OF THREE X-RAY SOURCES IN THE SAGITTARIUS REGION*

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Received 1969 October 16

ABSTRACT

A large-area modulation collimator aboard a sounding rocket was used to study the angular sizes of three galactic X-ray sources (GX 349+2, GX 9+1, GX 17+2) in the Sagittarius region. In each case an upper limit of 120″ was obtained for the full-width angular size.

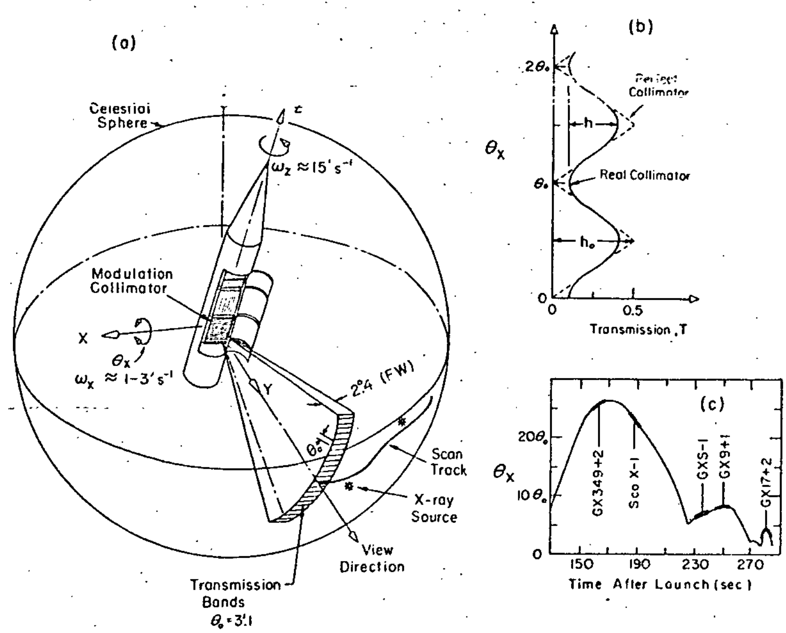

FIG. 1.—The experiment. (*a*) Instantaneous regions (transmission bands) of the celestial sphere viewed by the X-ray detectors; (*b*) modulated response of the collimator to a point source ($\theta_0 = 3'.1$); (*c*) modulation motion θ_x of payload during flight.

THE ASTROPHYSICAL JOURNAL, Vol. 159, February 1970

II-2

POSITIONS OF X-RAY SOURCES IN THE SAGITTARIUS REGION*

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Received 1969 December 16

ABSTRACT

A rocket experiment yielded data concerning the celestial positions and intensities (1.5–8 keV) of twelve X-ray sources in the region of Sagittarius. Comparison with data from other experiments yields no clear evidence for gross time variations in the intensity of these sources.

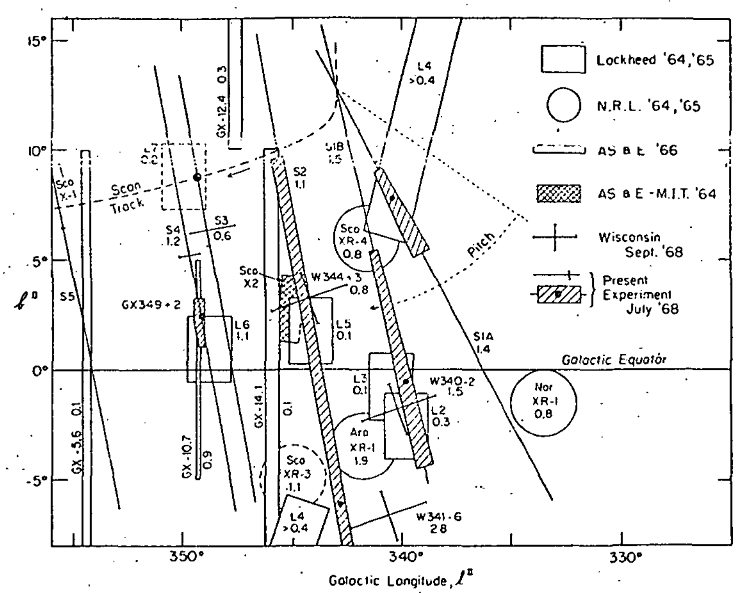

FIG. 4.—Lines of position for data peaks S1A–S5 and a summary of the results of other groups. Source designations and reported intensities (counts cm^{-2} sec^{-1}) are shown. Due to different counter efficiencies, intensities should be compared only if they were reported by the same group. Each hatched area represents the 90% error limits obtained from this experiment and, in the case of S4, other published results. Each large dot indicates our estimate of the most probable source position as deduced from all the data shown in this figure. Data of other groups are taken from: Lockheed (Fisher *et al.* 1968); NRL (Friedman *et al.* 1967); AS&E (Gursky *et al.* 1967); AS&E-MIT (Clark *et al.* 1965); and Wisconsin (Bunner *et al.* 1969). The dates listed in the key refer to the time the experiment was performed. We have not included NRL sources which have error limits $\geq 2°$.

THE ASTROPHYSICAL JOURNAL, Vol. 157, July 1969

II-3

INTERSTELLAR ABSORPTION OF 10-Å X-RAYS*

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Received May 26, 1969

ABSTRACT

Measurements of the 10-Å flux of X-rays from sources in the Scorpio-Sagittarius region give clear evidence for interstellar absorption, with a column density of at least 1×10^{22} H atoms cm^{-2}. In contrast, the X-ray flux from the Crab Nebula shows no evidence for a cutoff down to 12 Å (1.0 keV). This yields an upper limit for the average gas density between the Earth and the Crab Nebula of 0.5 H atom cm^{-3}.

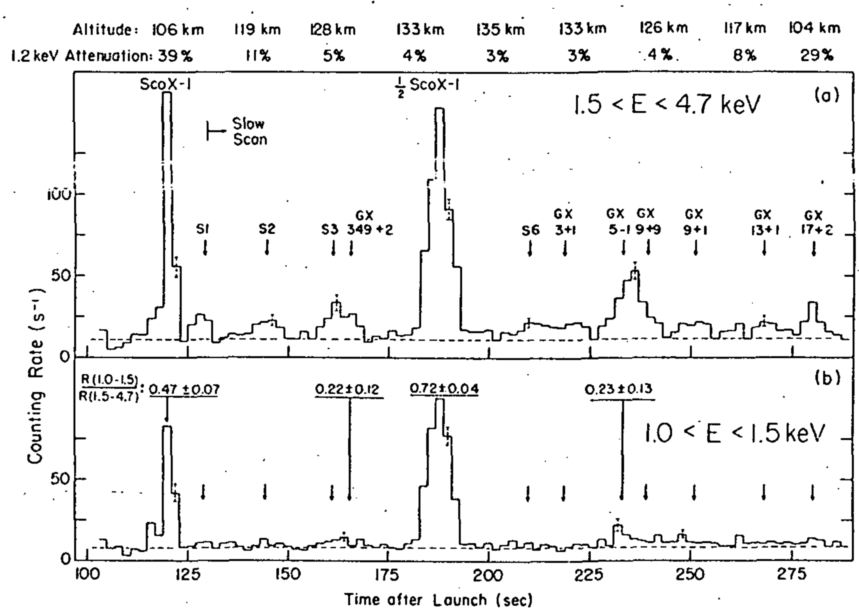

FIG. 2.—Counting rate versus time for the Scorpio-Sagittarius sources in the energy intervals 1–1.5 and 1.5–4.7 keV. Data are taken from three aluminum-window proportional counters (*D*, *F*, and *G*). Sources with positions known to within ~1° have previously been designated GX $l^{II}b^{II}$ (Bradt *et al.* 1968), with the exception of GX349+2. The latter position is based in part upon data from this flight (Mayer, Bradt, and Rappaport 1969) and from earlier work (Gursky, Gorenstein, and Giacconi 1967; Fisher *et al.* 1968). Rocket altitude and atmospheric attenuation at 1.2 keV are listed at the top of the figure. The 1–1.5-keV X-rays from Sco X-1 at $t \sim 120$ sec suffer an atmospheric attenuation of about 40 percent as expected.

(Reprinted from Nature, Vol. 222, No. 5195, pp. 728–730, May 24, 1969)

X-Ray and Optical Observations of the Pulsar *NP* 0532 in the Crab Nebula

III-1

by

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California Institute of Technology,
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The existence of a strong pulsed X-ray signal from the pulsar *NP* 0532 is confirmed. The phases and the shapes of the X-ray and optical pulses are compared.

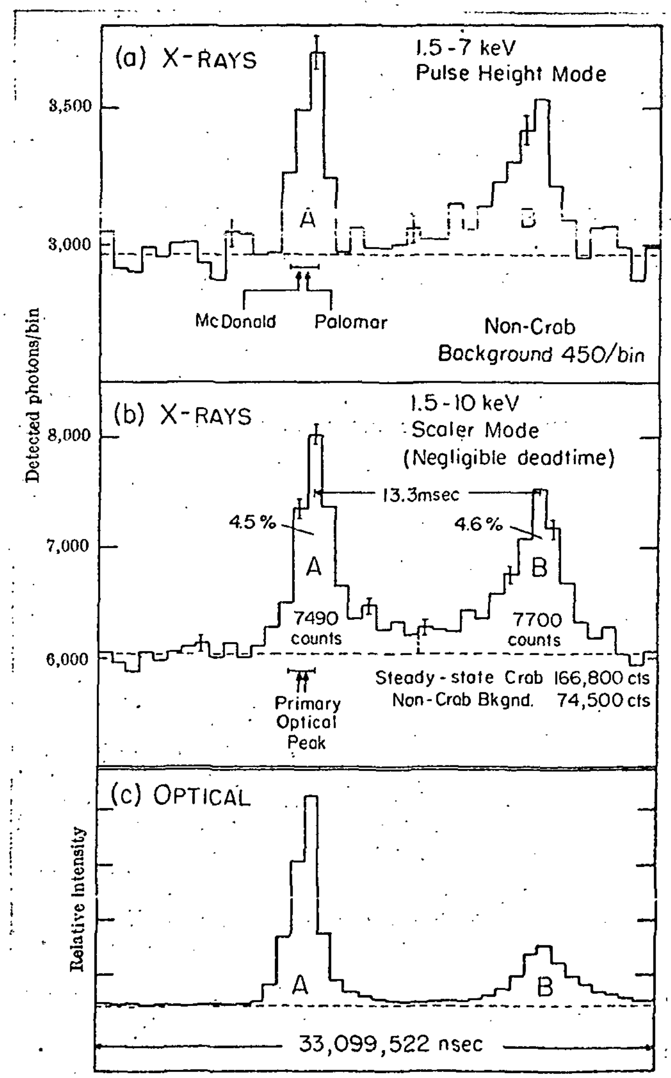

Fig. 1. *a* and *b*, X-ray data obtained during 150 s of observations and superimposed, into 40 bins, with the apparent period of the pulsar at McDonald Observatory, 33·099522 ms. The data for the two modes of signal processing are shown. Most of the X-ray photons in (*a*) are included in (*b*). (*c*) The optical data of ref. 6 integrated into 41 bins for comparison of pulse shapes. The relative phase of the X-ray and optical pulses are shown in (*a*) and (*b*). The principal optical pulse is coincident with the X-ray pulse *A* within 1 ms.

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X-Ray Observations of Pulsars

by
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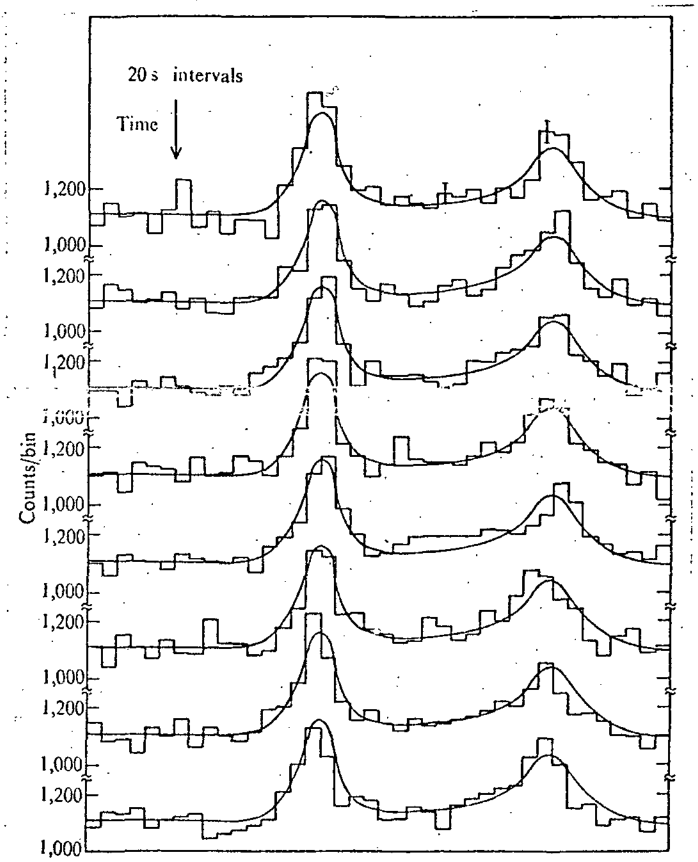

Fig. 2 X-ray data (1.5–10 keV) for NP0532 broken into eight intervals of 20 s. Each histogram has superimposed on it the solid curve which represents the average X-ray pulse profile determined from 190 s of data (Fig. 1).

THE ASTROPHYSICAL JOURNAL, 161:L161–L167, September 1970

IV -1

PRECISE LOCATION OF SAGITTARIUS X-RAY SOURCES WITH A ROCKET-BORNE ROTATING MODULATION COLLIMATOR

H. W. SCHNOPPER, H. V. BRADT, S. RAPPAPORT, E. BOUGHAN, B. BURNETT, R. DOXSEY, W. MAYER, AND S. WATT
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Received 1970 July 2

ABSTRACT

We have measured with high precision (about 1′–2′) the celestial positions of four X-ray sources (GX3+1, GX5−1, GX9+1, GX17+2) in the Sagittarius region. The experiment was performed with two independent rocket-borne rotating modulation collimators backed with proportional-counter detectors sensitive in the energy range 1.5–8 keV. High-precision aspect data were obtained by star photography which was directly referenced to the collimator grids.

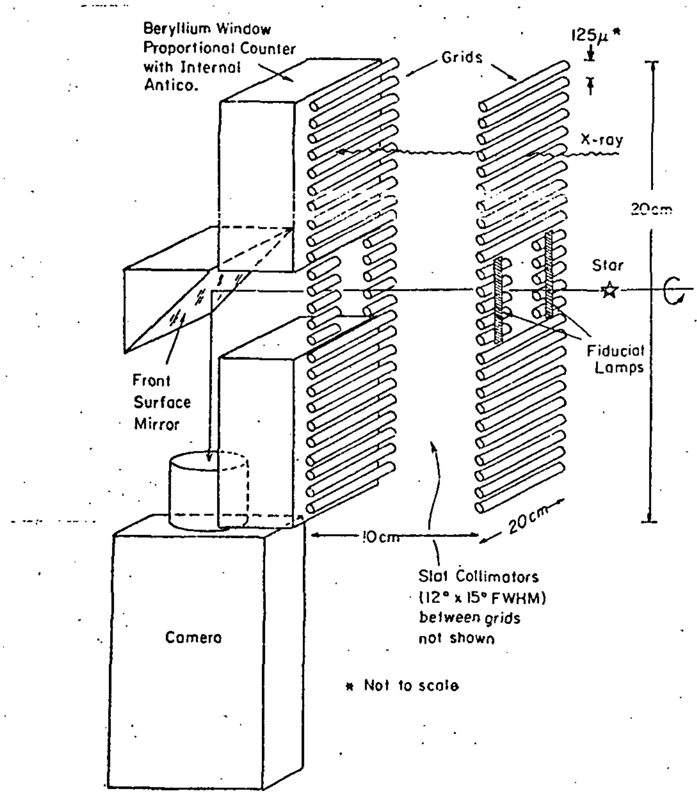

FIG. 1.—One of the two independent modulation collimator systems on the payload. The galactic-center region was viewed while the payload rotated about the pitch axis.

THE ASTROPHYSICAL JOURNAL, 161:L169–L172, September 1970

IV-2

AN OPTICAL SEARCH FOR THE X-RAY SOURCES GX3+1, GX5−1, GX9+1, AND GX17+2*

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AND

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Received 1970 July 9

ABSTRACT

A search to $B = 17$ for the optical counterparts of four sources of galactic X-rays ($b^{II} < 1\overset{\circ}{.}5$) yielded no clear candidates. The previously reported unusual ultraviolet object in the vicinity of GX3+1 has been excluded as an optical counterpart of this source by the new, more precise X-ray position.

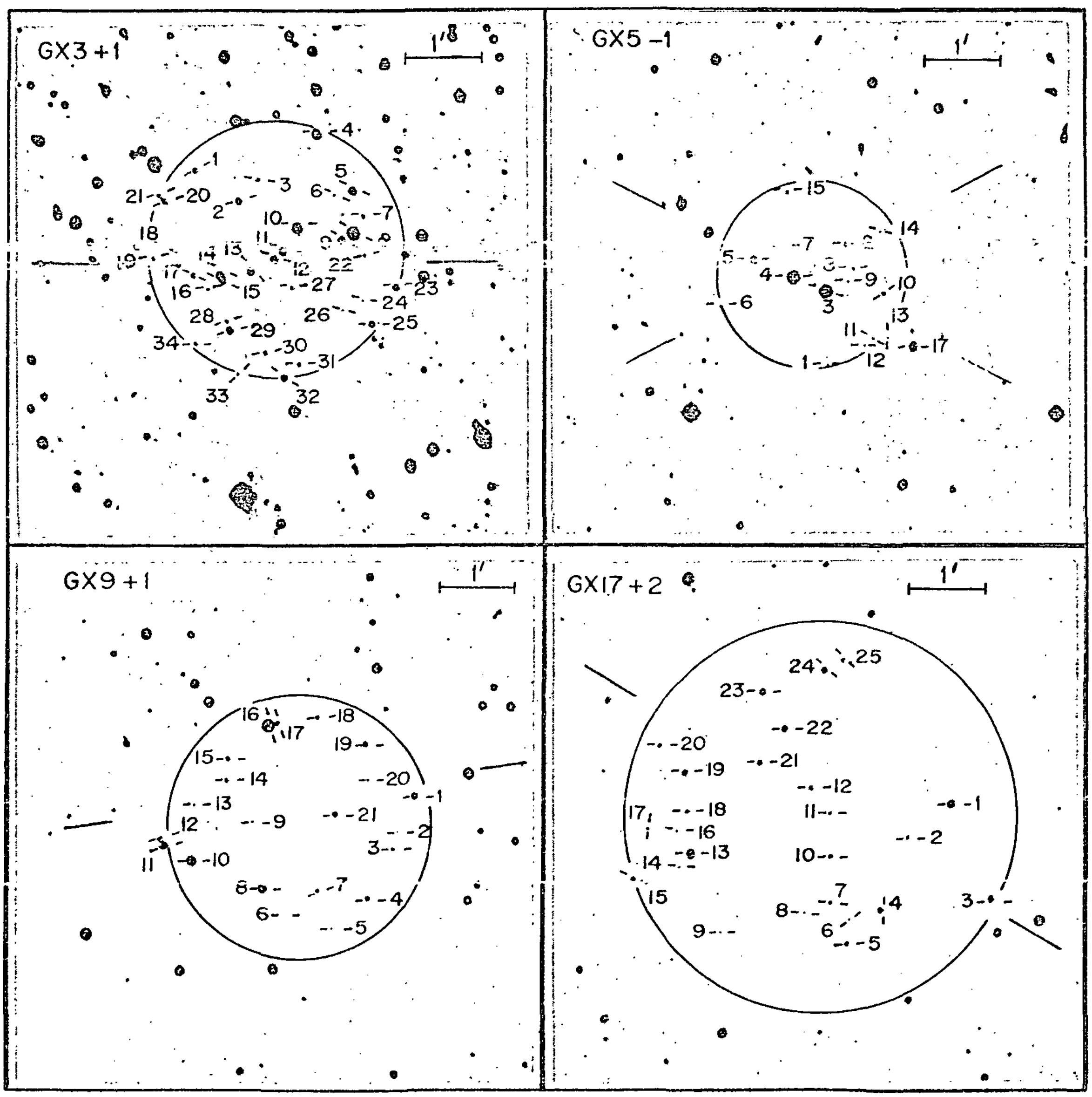

FIG. 1.—Blue photographs of the regions containing the X-ray sources. North is up and east is to the left. Circles define the "weighted average" regions given in Table 1 of Schnopper *et al.* (1970). Straight line segments indicate the long axes of the 7ʹ.5 × 2ʹ regions for which slitless spectra were obtained. Two such spectra were obtained for GX5−1. Object 1 in GX5−1 appears to be a triplet on our 60-inch plates. Copyright *National Geographic Society–Palomar Sky Survey.*

THE ASTROPHYSICAL JOURNAL, 168:L43–L47, 1971 September 1

IV-2

A SEARCH FOR X-RAY PULSATIONS FROM CYGNUS X-1*

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Received 1971 July 1

ABSTRACT

X-ray data from Cyg X-1 with a timing resolution of 1 ms have been obtained during a sounding-rocket flight. We find flaring activity on time scales down to 50 ms in which the X-ray intensity changes by a factor of 2. There are no regular X-ray pulsations which comprise more than 5 percent of the total X-ray flux in the range 0.010–1.0 s. About 30 percent of the X-ray intensity is modulated with periodicities in the range 1.3–5 s.

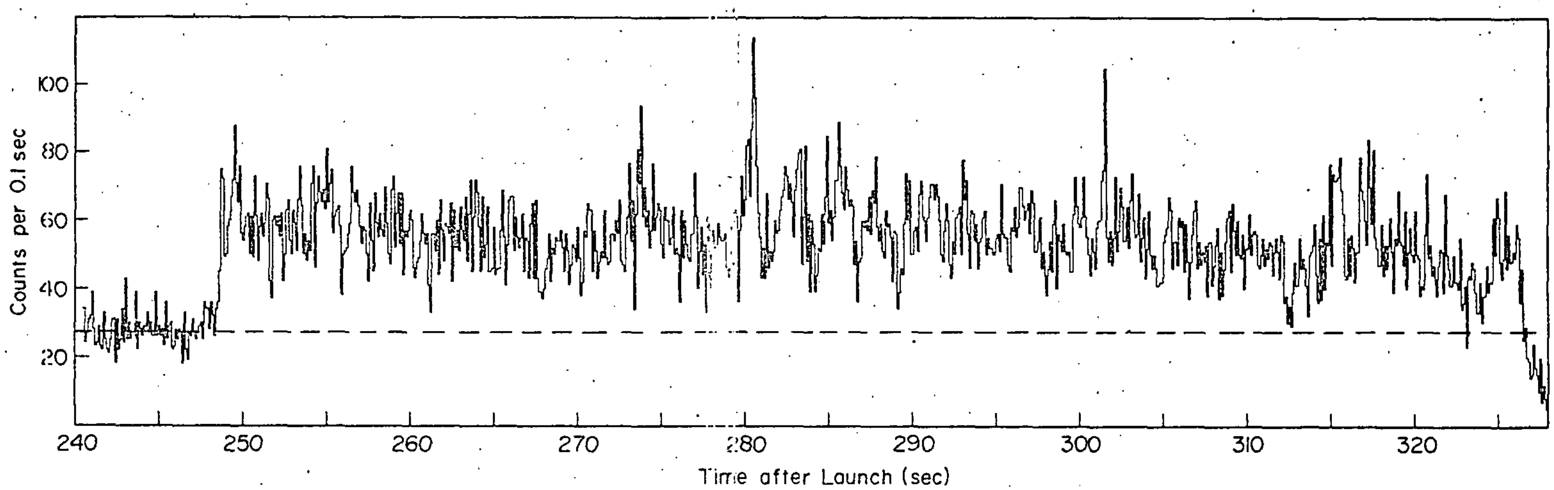

FIG. 1.—Cyg X-1 counting-rate data. Cyg X-1 entered the field of view at ~250 s (after launch). The source was viewed until the payload door closed at 325 s. *Dashed line*, background counting rate, due mostly to the "isotropic" X-ray flux.

THE ASTROPHYSICAL JOURNAL, 161:L173–L174, September 1970

IV - 3

A SEARCH FOR RADIO EMISSION FROM FOUR X-RAY SOURCES NEAR SAGITTARIUS

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C. R. PURTON
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AND

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Received 1970 July 9

ABSTRACT

Upper limits have been placed on the ratios of radio (4.6 cm) to X-ray (4.6 Å) flux densities from four X-ray sources in the region of the galactic center. From these results we conclude that GX3+1, GX5−1, GX9+1, and GX17+2 are markedly different from presently identified supernova remnants.

IV -4

1-10 keV X-ray Sky near the Galactic Centre

by

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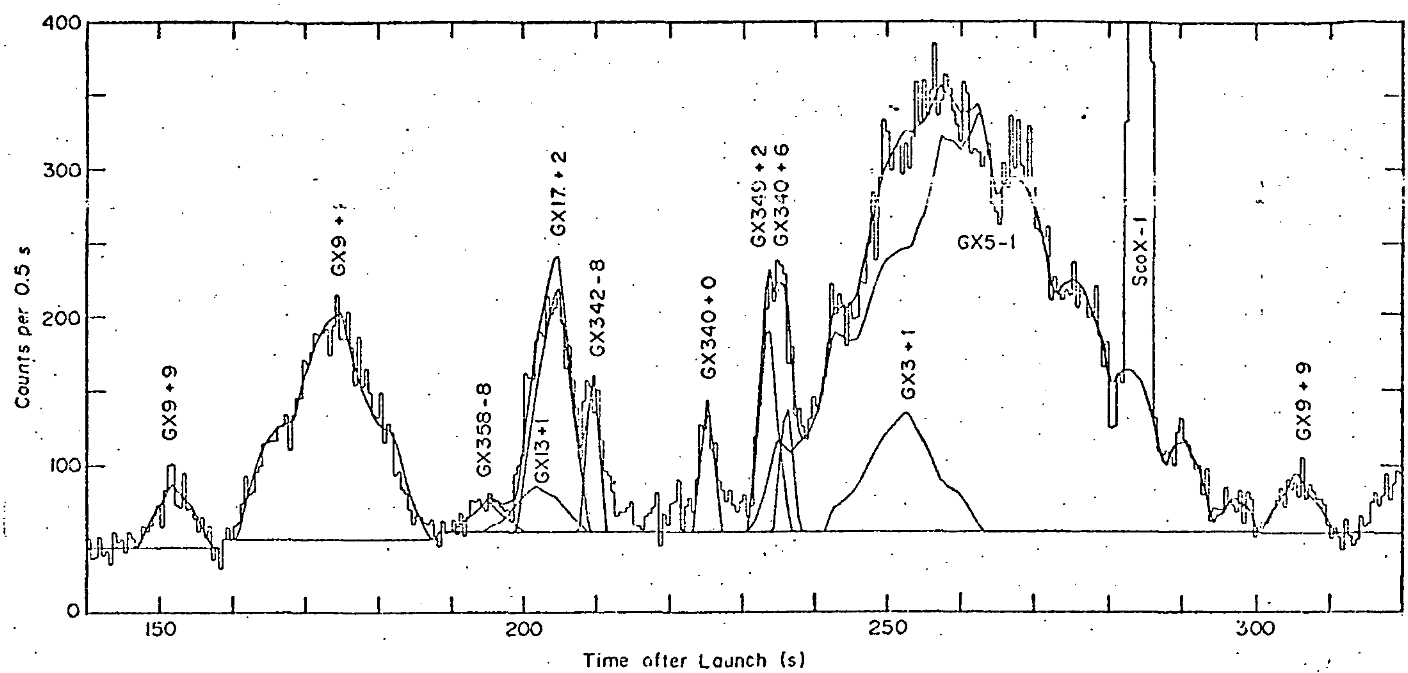

Fig. 2 Histogram of counting rate versus time for the rotating slat collimator (Experiment IV). The lines represent the expected response for the "best fit" source positions and intensities. In a multiple-source region, the outer curve gives the sum of the responses. The complex structure in GX5–1 arises from a leaking control jet (roll axis) and the abrupt jet firings which overcome its effect.

THE ASTROPHYSICAL JOURNAL, 168:L17–L20, 1971 August 15

VI - 1

ON THE LOCATION OF CYGNUS X-1*

S. RAPPAPORT, W. ZAUMEN, AND R. DOXSEY
Physics Department and Center for Space Research, Massachusetts Institute of Technology
Received 1971 June 21

ABSTRACT

The position of Cyg X-1 is determined with a precision of ~30″ with a rocket-borne rotating modulation collimator.

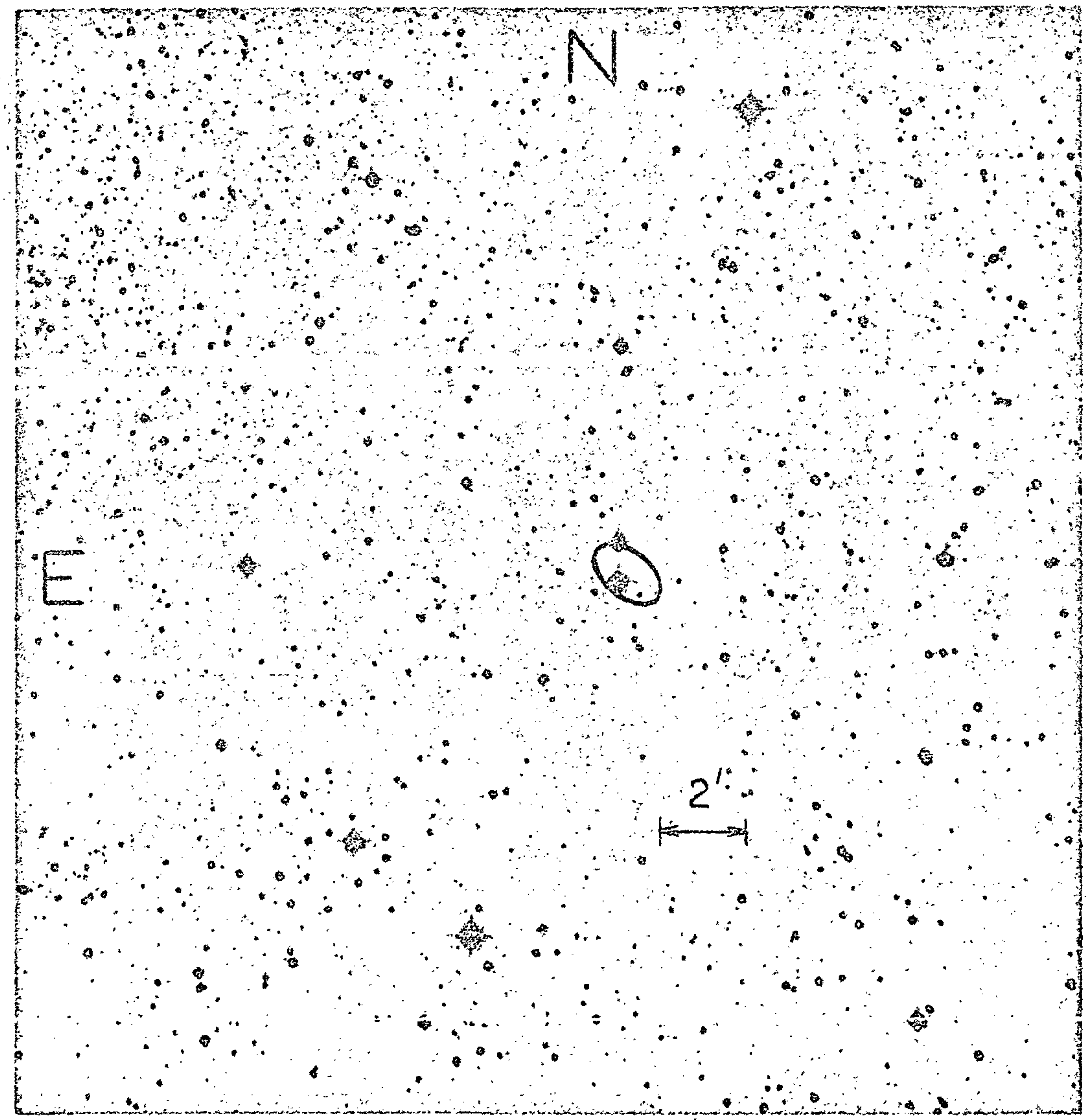

FIG. 3.—Enlargement of a *Palomar Sky Survey* print (© *National Geographic Society*) which contains the MIT location for Cyg X-1. Ellipse denotes the region of uncertainty (3σ), and is centered on the best position for Cyg X-1: $\alpha(1950) = 19^h56^m27^s.6$, $\delta(1950) = 35°04′07″$. Ellipse encloses the position of a newly discovered radio source (Hjellming and Wade 1971).

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THE ASTROPHYSICAL JOURNAL, 169:L93–L97, 1971 November 1

VI-3
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GX 349+2 AND GX 340+0: LOCATIONS AND X-RAY PULSATION LIMITS*

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Received 1971 September 10

ABSTRACT

The celestial positions of GX 349+2 and GX 340+0 are determined with a precision of better than 1 arc min with a rocket-borne rotating modulation collimator. Limits on periodic X-ray pulsations from these sources are set.

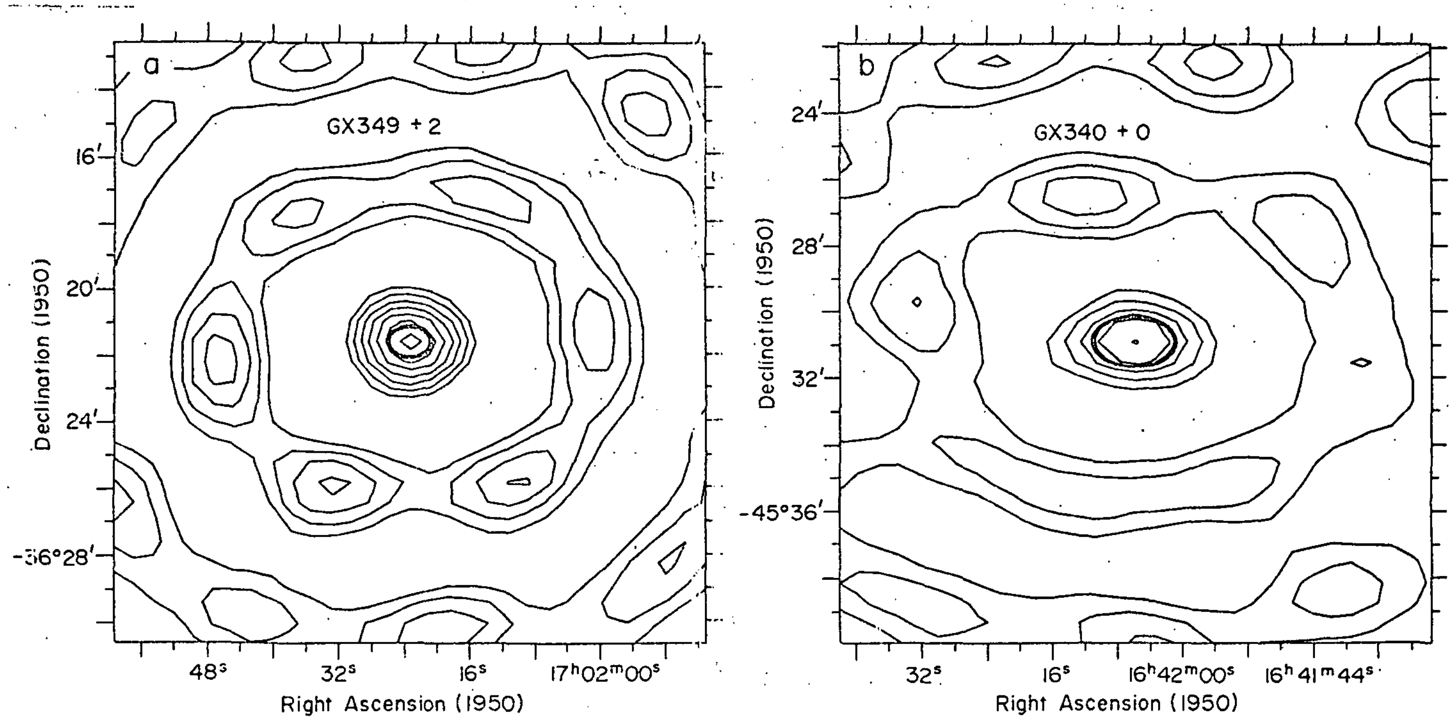

FIG. 1.—Contour plots of the correlation maps for (*a*) GX 349+2 and (*b*) GX 340+0. Contour levels are plotted in steps of ~1.5 standard deviations above the average background level. The calculated response of the modulation collimator to GX 349+2 was subtracted from the raw counting-rate data to produce the correlation map for GX 340+0 (see Schnopper *et al.* 1970). For each source the dark ellipse represents the error limits (90 percent confidence). The elongations of the correlation contours are a result of the difference between the right-ascension and the declinaton scale factors.

VI - 4

Detection of Radio Emission from GX9+1

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R. M. HJELLMING
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National Radio Astronomy Observatory,
Green Bank,
West Virginia 24944

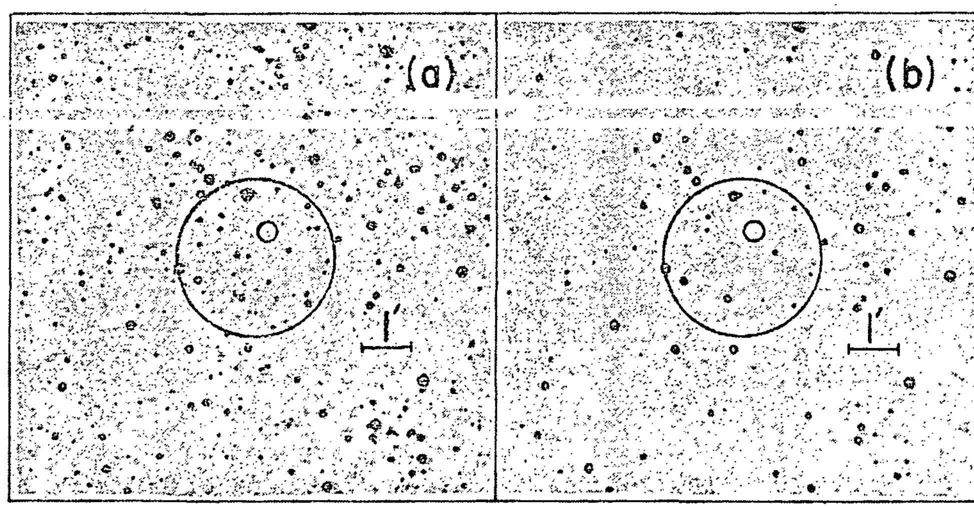

Fig. 1 Enlargements of the red (*a*) and blue (*b*) *Palomar Sky Survey* prints (copyright National Geographic Society) of the region near GX9+1. North is up and east is to the left. The large circle in each print represents the X-ray source location (3σ) (ref. 6). The small circle encloses the radio source location and, for clarity, is drawn twice the size of the quoted uncertainty.

THE ASTROPHYSICAL JOURNAL, 176:L15–L18, 1972 August 15

VI-5

RADIO SEARCH FOR THE PULSING X-RAY SOURCE IN HERCULES*

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Received 1972 May 26

ABSTRACT

The region of the celestial sphere near the pulsing X-ray source in Hercules (2U 1705+34) has been searched for radio emission with the NRAO three-element interferometer. The search was conducted during a period when the Hercules source was in its 27-day state of low X-ray luminosity. Four weak radio sources, which may be considered as candidates for the radio counterpart of this X-ray source, were detected.

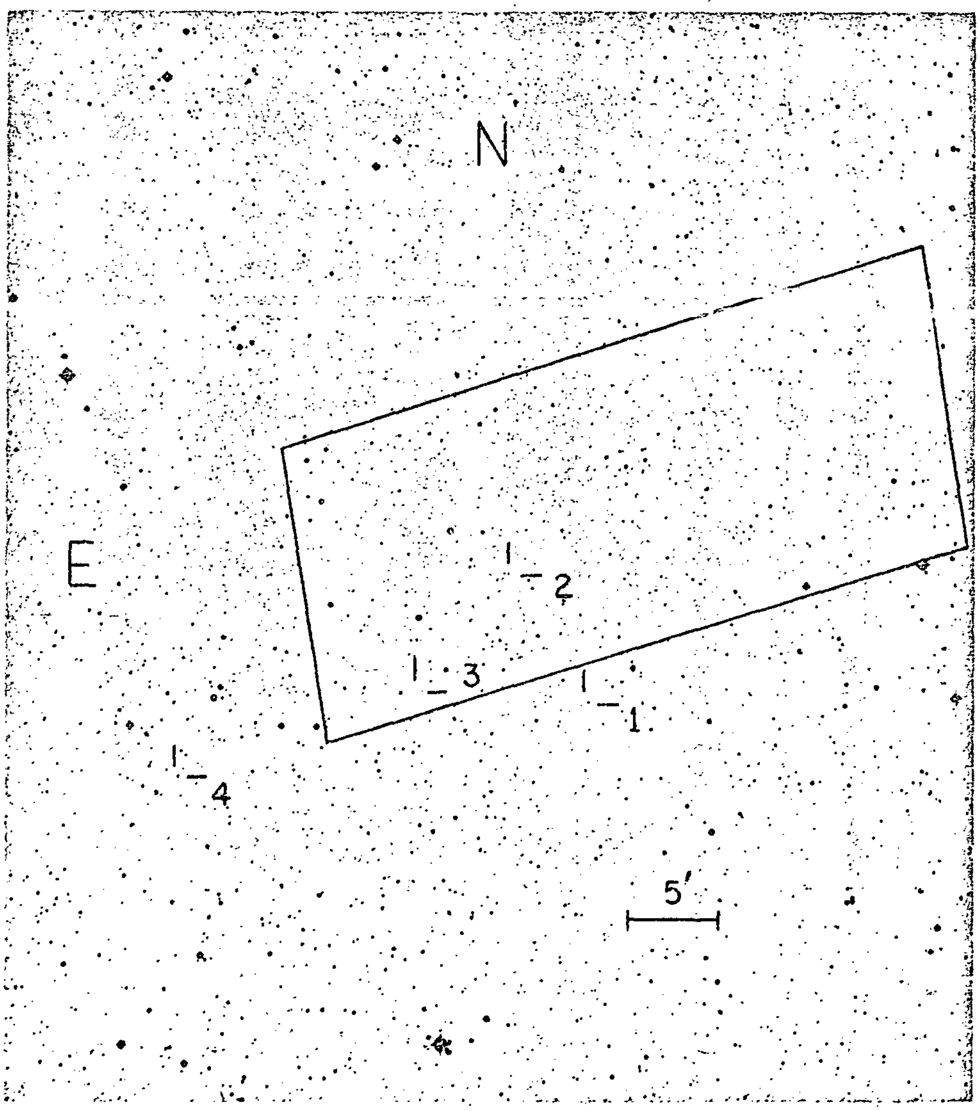

FIG. 2.—Enlargement of a *Palomar Sky Survey* print (©National Geographic Society) of the Her X-1 region. The parallelogram represents our estimate of the present location uncertainty for this source. The pointers indicate the four radio sources detected at 2695 MHz in this search. The source numbers are the same as in table 1.

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 43, NUMBER 6 JUNE 1972

A Sealed Titanium Window Proportional Counter for the Detection of $\frac{1}{2}$ keV X Rays*

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(Received 22 February 1972; and in final form, 20 March 1972)

A sealed Ti window proportional counter sensitive to x radiation in the energy range 0.35–0.45 keV and >1.5 keV is described. Measurements of the Ti mass absorption coefficients and a graphical summary of the literature values are presented. For a proportional counter with a 930 $\mu g/cm^2$ (2.1 μ) Ti window, the peak efficiency at 0.45 keV is found to lie between 4.6% and 7.1%. An application in x-ray astronomy involving a rocket observation of Sco X-1 is discussed.

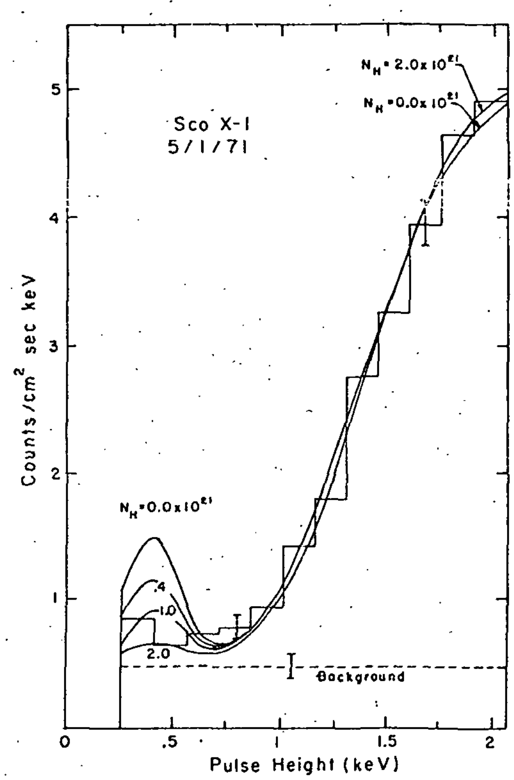

FIG. 4. X-ray pulse height distribution from Sco X-1. The dashed line represents the nonsource background level. The solid curves are the calculated counter responses to Sco X-1 with various assumed neutral hydrogen column densities between the Earth and the source.